

REPORT OF ACTIVITIES
J. M. STUCKEY
SEPTEMBER 28, 1995 TO DECEMBER 6, 1995

I. ET LWT INSULATION

A. NCFI 24-124 FOAM (HCFC 141-B BLOWING AGENT)

1. This foam system has been fully qualified for use on the ET LWT replacing CPR-488 foam, and is now being successfully applied to flight hardware. This system will be dropped from bi-monthly unless something unexpected happens.

B. SS-1171 FOAM (HCFC 141-B BLOWING AGENT)

1. This foam system has also been fully qualified for use on the ET LWT replacing BX-250 foam. MAF is in the process of doing validation sprays. This effort has been slowed in some cases by equipment malfunction, and in some hand-spray areas the spray technique needs improving. No major difficulties are expected in completing this effort.

C. PDL-1034 FOAM (HCFC BLOWING AGENT)

1. Validation pours are still in progress for this new foam system that has been qualified for use on the ET LWT replacing PDL-4034. No major difficulties are anticipated in completing this effort.

II. ET SLWT INSULATION

A. NCFI 26-93 FOAM (LITE NCFI 24-124 FOAM ADJUSTED FLAME RETARDANTS)

1. The first lot of this foam was blended by LMC/MSFC at MSFC and shipped to MAF. MAF has completed all planned sprays on this material, and the data that has been evaluated is quite favorable. Strength data on NCFI 26-93 foam appears to be comparable to that of NCFI 24-124 at a density of 0.1 lb./ft³ lower than that of NCFI 22-124. Lot #2 of this material (blended by NCFI) is expected around December 1, 1997.

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Unclass

B. 2195 Li/Al COMBINED ENVIRONMENT TANK

1. This tank has been fully instrumented, insulation applied, and is ready for testing. NCFI 24-124 foam was applied to the test area, and there is a 9" x 9" patch of hand packed SLA. As I remember hand packed SLA does not work too well at cryogenic temperatures, and I would not be surprised if this patch of SLA-561 did not come off. Although this test will not be considered a TPS test due to number of instruments bonded on the tank skin, it will provide useful information on how the TPS performs.

C. NEW LIGHT WEIGHT INSULATION FOR THE LH₂ TANK AFT-DOME

1. LMC/MSFC enhanced the strength of 2.15 lb/ft³ density foam (NCFI 26-93) by making adjustments to the flame retardants in NCFI 24-124 foam (2.26 lbs/ft³ density). If the same adjusted flame retardants were made to NCFI 24-124, it would be expected that a stronger foam would result, and perhaps this stronger foam could be used on the aft dome. If this could be done some 50 to 60 lbs. insulation weight could be saved.

2. To see if this proposal has any merit, it is suggested that thermal/vacuum tests at a heating rate of 10 BTU/ft²-sec be run on the following foams: NCFI 24-57, NCFI 24-124, NCFI 26-93, NCFI 24-124 adjusted flame retardant.

III. THERMAL SPRAY APPLICATION OF POLYMER COATINGS

A. THERMALLY SPRAYED POLYIMIDE RESIN COATING

1. The thermally sprayed polyimide coating applied by Applied Polymer System had good adhesion to both 2219 Aluminum and stainless steel, and also showed good protection of the metal in the 30 day salt spray test except in the scribed area. Unfortunately, the aluminum was heated to very high temperatures that destroyed the temper. Rocketdyne is attempting to get Applied Polymer System to do some work trying to get a good coating while holding down the temperature of the aluminum. To date they have not obtained any information from Applied Polymer System on any success that they have had.

2. LMC/MAF was contacted to see if they had any salt spray data on the epoxy primer used on the ET that did not have any corrosion inhibition. I understand that they expect to receive some of the base primer without corrosion inhibition in the near future. This data would be helpful in determining if these might be better polymers than the epoxy for base resins in a new primer system.

IV. MISCELLANEOUS

A. LINER FOR A COMPOSITE LOX TANK

1. There is some data that says that Kapton (polyimide) film is LOX compatible. However, this polymer still has some hydrogen on the polymer chain that could react with LOX. Also, I know of no LOX compatible adhesive that would be needed to bond sections of the polyimide films to themselves.
2. In searching for data on the LOX compatibility of Kapton film, some information was found on DuPont Kapton films coated on 1 or both sides with FEP Teflon. DuPont was contacted for information on these films, and based on the information they furnished us, a few pounds of a film consisting of 1 mil Kapton with 0.5 mil FEP Teflon on one side was ordered. With this material we hope to form a liner by heating sealing sections of the film together that will have a FEP Teflon surface exposed to LOX, and a Kapton surface for the prepreg to bond to that will form the composite tank. With this liner a 350⁰F to 400⁰F cure temperatures for the composite should have no effect on the liner.
3. It is envisioned a preliminary program similar to this will be run after the film has been received. Efforts will be done to see how well we can heat seal sections of films together (visual inspection and peel test). The effect of LN₂ on the bond will be tested to see if LOX temperatures adversely effects the bond strength. Cure of this laminates to heat sealed sections of the film will be evaluated to see how well the laminate bonds to the Kapton film and if the cure temperature has any bad effect on the bond of the film to itself.

If the bond of the Kapton film to the laminate appears inadequate, various treatments of the Kapton film such as abrasion to improve adhesion should be evaluated. Finally a small scale liner should be fabricated and then checked for leaks. If leaks are found, the potential for repairing leaks by the application of heat and pressure to the leaking area should be investigated. Repairs should continue until a leak proof liner is obtained. Positive results from a program of this magnitude would show that a liner for a composite LOX tank is feasible.

B. AEROGELS FOR INSULATION ON CRYOGENIC TANKS

1. Aerogels are molecular-scale open-cell foams that are made using supercritical processing (over 1000 psi pressure at 300°C or higher). Processing condition and time required are reduced by using liquid CO₂ supercritical drying. Aerogels have a high porosity, but passage of air and gelling solvents through aerogels are extremely slow due to the close packing of molecular-scale particles. Densities of the aerogels range from 0.05 to 0.44 g./cm³.

2. Silica aerogels are made from methyl or ethyl ortho silicates in a alcoholic medium. The thickness of aerogel panels are usually limited to approximately 3cm thick because of the time required to leach out gelling solutions. Silica aerogels are not very strong. Using Hardman A-85 polyurethane adhesive they got a bond strength to a substrate with 0.38 g./cm³ (about 23 lbs/ft³) aerogel of about 15 psi; with 0.15g./cm³ aerogel a bond strength of 2.5 psi. With silica aerogel there would be no problem of oxidation in an elevated temperature environment.

3. Organic aerogels are made by the aqueous polycondensation of (1) resorcinol with formaldehyde and (2) melamine with formaldehyde. Organic aerogel precursor can be cast to near net shape and will suffer a uniform linear shrinkage of about 25% during pyrolysis. Carbon aerogels at a density of 0.1 g./cm³ has a surface yield strength of about 30 psi and can be elastically strained up to several percent. Carbon aerogels would have to be protected from oxidation in an elevated temperature environment.

4. Before aerogels can be used on flight vehicles, it would need to be tested to be sure that the panels would not destruct from rapid evacuation. I do not believe the aerogel could be bonded directly on a LH₂ tank because I believe that cryopumping would occur, and when the LH₂ level fell below the cryopumped air, the change from liquid to gaseous air would blow the aerogel off the tank. I presume that aerogel panels will have to be made in desired shape and sizes, and that they cannot be thermally or otherwise formed to desired shape. I have no information on how large aerogel panels can be made, and if the size increases can cracking be prevented?

5. Based on the information I have, the most attractive use for aerogel insulation would be on reusable flight vehicles (one stage to orbit and return). This is based on the assumption that a refractory coating can be applied over the aerogel that will allow the aerogel to survive both ascent and re-entry heating. If this is the case, then the total weight of insulation on a LH₂ tank would be around 1.0 to 1.5 lbs./ft². the break-down of insulation weight follows:

Approx. lbs./ft ²	Material
0.2	1.0 inches of 2.4 lb/ft ³ polyisocyanate foam (0.5 inch could be sufficient).
0.1	Adhesive to bond aerogel to foam (would also cover wt. of primer on tank).
0.7	Assuming 3 cm. layer of aerogel, with a density of 0.1g./cm ³ (about 0.5 lbs/ft ³), and a 100 micron refractory coating on the aerogel with a density of 5.
----- 1.0	Total

Thermal diffusion time constant for a 3 cm. thick layer of carbon aerogel is approximately one hour. Since coated aerogel could oxidize at joints or small leaks, it may be desirable to increase the thickness of refractory coating to attempt to eliminate these potential oxidization areas and to enhance the coatings ability to resist erosion from ascent and reentry. It might also be desirable to enhance the strength of the carbon aerogel by increasing the density. These increases could increase the total weight of the TPS to approximately 1.75 lbs./ft².

6. The potential of aerogels for insulation for a single stage to orbit flight vehicle is sufficient for at best NASA keeping abreast of the aerogel development. As resources become available, I think the following tests should be considered:

- a. A small sample of sealed carbon aerogel (with refractory coating if possible) should be exposed to rapid evocation equivalent to that experience in ascent. This is possibly not necessary, but it is such a simple, inexpensive test that it should be done to enhance safety and confidence.

- b. Testing for cryopumping is not necessary as long as there is a layer of foam insulation between the aerogel and the LH₂ tank wall. I believe the foam insulation layer is necessary to eliminate all possibilities of cryopumping occurring.
- c. I propose to bond the aerogel to the foam insulation with a silicone adhesive such as RTV-560 or GX6300, and also the aerogel panels to each other.
- d. There is probably some effort needed in learning to apply the refractory coating to the aerogel.
- e. A best effort possible is needed to calculate how hot the adhesive bond line between the foam and the aerogel may get during reentry.
- f. Tests are needed to see how well this insulation concept will stand-up to aero-shear and aero-heating during reentry, and also radiant heating simulating aft dome conditions during ascent.

Items 6a and 6e should be done as soon as feasible because information developed in these tests will be influential in determining how to proceed. Only minimum funding will be required for these two tests, and item 6e is the most critical. The aerogel panel used in item 6a could possibly be used to develop information needed for item 6e. Item 6e should be updated periodically as more information becomes available.

7. If the bond line temperature between the foam and the aerogel is much above 300°F, then it would be necessary to consider a foam with higher temperature capabilities such as Rohacell or phenolic foams.

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